New records of parasitoid flies (Diptera, Sarcophagidae) in Nearctic species of *Trimerotropis* Stål (Orthoptera, Acrididae, Oedipodinae, Trimerotropini)

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Abstract

The genus *Trimerotropis* Stål, 1873 (Orthoptera: Acrididae) is a speciose group of American grasshoppers, comprising 49 recognized species. Despite its diversity, published records of parasitoid associations with *Trimerotropis* are scarce, with only a single published record of a sarcophagid fly, *Blaesoxipha* (*Acridiophaga*) *caridei* (Brèthes, 1906) (Diptera: Sarcophagidae), from *T. ochraceipennis* (Blanchard, 1851) in Chile. Here, we report two new hosts for *B.* (*A.*) *angustifrons* (Aldrich, 1916): *T. melanoptera* McNeill, 1901, in New Mexico, USA, and *T. pallidipennis* (Burmeister, 1838), in California, USA. The records are described herein, including illustrations and diagnostic characters of both hosts and their parasitoid fly. These findings significantly expand the known host range for this Nearctic parasitoid and contribute to the limited understanding of host–parasitoid dynamics in this ecologically important genus of grasshoppers.

Keywords

Blaesoxipha, *Conozoa*, flesh flies, grasshoppers, oviposition strategy, Pallid-winged Grasshopper

Introduction

The genus *Trimerotropis* Stål, 1873 is a species-rich group of grasshoppers restricted to the American continent, with a range extending from Canada to Chile and Argentina, and particularly abundant in desert and semi-desert regions (Rehn 1939, Otte 1970, 1984). The genus currently comprises 49 recognized species (Cigliano et al. 2025), and its members are often difficult to distinguish morphologically (Capinera et al. 2004). The morphological variation among species makes it challenging to establish a comprehensive characterization of the genus without reference to other genera and the habitat. Key diagnostic characters include the median ridge of the pronotum rarely forming a sharp ridge, usually very low on the metazona; the pronotal crest always cut by two sulci; the forewing bands crossing the dorsum (in species that do not live in sandy habitats); the eyes relatively large; the hindwings usually with a clearly defined outer dark band; and the basal area of the hindwings yellow, yellow-green, or blue, never orange or red (Otte 1984).

Knowledge of parasitoid associations with *Trimerotropis* species is limited. To date, there are no published records of parasitoid wasps in *Trimerotropis* species, although they are documented prey of sand wasps of the genus *Tachysphex* Kohl, 1883 (Hymenoptera: Crabronidae) (Evans 1970, Kurczewski 1991, 2010). The only confirmed dipteran parasitoid record is the flesh fly *Blaesoxipha* (*Acridiophaga*) *caridei* (Brèthes, 1906) (Sarcophagidae: Sarcophaginae), reared from *Trimerotropis ochraceipennis* (Blanchard, 1851) in Chile (Stuardo Ortiz 1943). In contrast to these parasitoid records, some kleptoparasitic Miltogramminae flies have been reported from paralyzed *Trimerotropis* individuals found as provision in sand wasp nests in the United States of America (USA) (Evans 1970).

A few groups of Sarcophaginae are commonly recorded as parasitoids of numerous lineages of grasshoppers (Pape 1996), with the speciose genus *Blaesoxipha* Loew, 1861 being the most relevant (Pape 1994). *Blaesoxipha* is a worldwide genus comprising more than 240 species in 10 subgenera (Pape 1996). Although grasshoppers are the most frequent hosts of *Blaesoxipha* species, hosts also include tenebrionid beetles and other orthopteroid insects (Pape 1994, 1996). Most species with known biology were recorded from only one or a few host species within the same genus, while some species within the subgenera *Acridiophaga* Townsend, 1917a, *Blaesoxipha*, *Kellymyia* Townsend, 1917b, *Servaisia* Robineau-Desvoidy, 1863, and *Tephromyia* Brauer & Bergenstamm, 1891 seem to utilize a broader range of hosts (Rees 1973, Pape 1994).

Here, we report two new host records for *Blaesoxipha* (*Acridiophaga*) *angustifrons* (Aldrich, 1916): *Trimerotropis melanoptera* McNeill, 1901 and *Trimerotropis pallidipennis* (Burmeister, 1838), in New Mexico and California, USA, respectively. The records are described, including notes on the diagnostic characters and the geographic distribution of both hosts and their parasitoid fly.

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Methods

Specimens of the two *Trimerotropis* species were collected in 2023 as part of the project "Why are species where they are? Identifying the interplay of the evolutionary, environmental, and biotic mechanisms driving niche diversification in Oedipodinae grasshoppers," conducted by Dr. Tereza Jezkova's team. *Trimerotropis pallidipennis* (Fig. 1A) specimens were collected near Mono Lake Navy Beach viewpoint, California (37.929883, –119.021017) (Fig. 1B) on 16 August 2023, whereas *T. melanoptera* (Fig. 2A) were collected near the National Scouting Museum, New Mexico (36.454135, –104.954271) (Fig. 2B) on 16 September 2023.

Grasshoppers were captured with entomological nets and euthanized in the field with acetone-charged kill jars. Since the project aimed to obtain material for genetic analyses, one femur from each individual was removed and preserved in vials containing 100% ethanol. During fieldwork, the remaining body was eviscerated by a small incision in the cervical membrane to remove the internal organs and placed in rectangular newspaper envelopes lined with cotton to hold the specimens. Approximately one week after fieldwork, the specimens were prepared for drying in the laboratory by placing them in an oven at 50 °C for 30 minutes. At this time, we discovered fly puparia from larvae that had emerged from some specimens inside the entomological envelopes. The entomological envelopes containing the puparia were then placed in zip lock bags to allow for adult fly development. The grasshopper vouchers were deposited in the reference collection of the Jezkova Lab Global Change Biology at Miami University, Oxford, Ohio. Host specimens were identified based on Otte (1984).

Specimens of adult Sarcophagidae were collected in 70% ethanol and sent to the Laboratório de Diptera of the Museu de Zoologia da Universidade de São Paulo (MZUSP), São Paulo, Brazil, for identification. To prevent collapse or deformation of the wings and other body parts, specimens were soaked in amyl acetate before pinning. For dissection of the male terminalia, the abdomens were detached from the pinned specimens, placed in 10% KOH solution, and heated to 60 °C for 10 min to soften the membranes and clear the tissues. The terminalia were then separated and heated for 10 min to lighten the structures. Both the terminalia and abdomen were neutralized in 5% acetic acid solution and rinsed with water. The abdomens were dried and glued back to the specimens, and the terminalia were placed in glycerin in plastic microvials and pinned to the respective specimens. Identification was based on Pape (1994) and confirmed by comparison with the holotype male of *Sarcophaga angustifrons* Aldrich, 1916 (Fig. 3) deposited in the National Museum of Natural History (USNM), Washington DC, USA (available on http://n2t.net/ark:/65665/30453cedd-1fb5-4129-aa41-ec3963703afe). The fly vouchers were deposited

Fig. 1. Record of *Trimerotropis pallidipennis* (Burmeister, 1838). **A.** Male, lateral habitus. **B.** Collection site, near Mono Lake Beach viewpoint, California, USA. Scale bar: 0.5 cm.

Fig. 2. Record of *Trimerotropis melanoptera* McNeill, 1901. **A.** Male, lateral habitus. **B.** Collection site, National Scouting Museum area, New Mexico, USA. Scale bar: 0.5 cm.

in the MZUSP collection. Morphological terminology follows Cumming and Wood (2017) and Giroux et al. (2010) for phallic structures. Photographs were taken with a Leica MC170 HD digital camera attached to a Leica MZ16 stereomicroscope using the Leica Application Suite version 4.12.0, stacked with Helicon Focus, and edited in Gimp 2.10.

Results and discussion

Larvae of *B.* (*A.*) *angustifrons* emerged from adults of *Trimerotropis* after collection but before the drying process. The larvae survived despite the grasshoppers having been submerged in acetone and subsequently eviscerated. The exact date of larval emergence and the time required for adult fly emergence could not be determined, as the fly puparia were found in entomological envelopes, with separate envelopes used for each *Trimerotropis* species.

A single puparium was found in the envelopes containing *T. pallidipennis*, from which an adult male successfully emerged. *Trimerotropis pallidipennis* is the most widely distributed Oedipodinae in the New World, ranging from southwestern Canada to at least central Argentina. This species can be easily confused with several other *Trimerotropis* species but can be recognized by the following combination of characters (Fig. 1A): distinct dark crossbands on the dorsal surface of the forewings; basal area of the hindwings pale whitish-yellow to yellow, consistently with a distinct black band; hind tibiae yellowish to pale brown; and posterior margin of the lateral lobes never bearing a small tooth. It primarily inhabits dry grasslands, including western prairies, desert grasslands, and desert scrub, and in North America, it is generally found at lower elevations (Otte 1984).

Two puparia were found in the envelopes containing *T. melanoptera*, but only one adult male successfully emerged (Fig. 4). *Trimerotropis melanoptera* is characterized by a very broad black band on the hindwings, a reddish abdomen, and a single pale band on the inner face of the hind femora (Fig. 2A), and it inhabits open grasslands and desert grasslands (Otte 1984).

The genus *Blaesoxipha* is mainly characterized by specimens having a posteromedian row of spines on the trochanter of the hind leg in both sexes and by characters of the male terminalia, such as the male cercus bent posteriorly, with the dorsal surface of the distal part covered with short erect spines, and the phallic vesica reduced or not developed (Fig. 4F) (Pape 1994, Giroux et al. 2010). Among the ten subgenera, *Acridiophaga* species are characterized by having the proepisternum setose and the male terminalia with the apical part of the juxtal lobes curving laterally or outwards (Fig. 4G) (Pape 1994). *Blaesoxipha* (*A.*) *angustifrons* is a Nearctic species, widely distributed from southern USA to Canada, and is very similar externally to *B.* (*A.*) *caridei*, a widespread

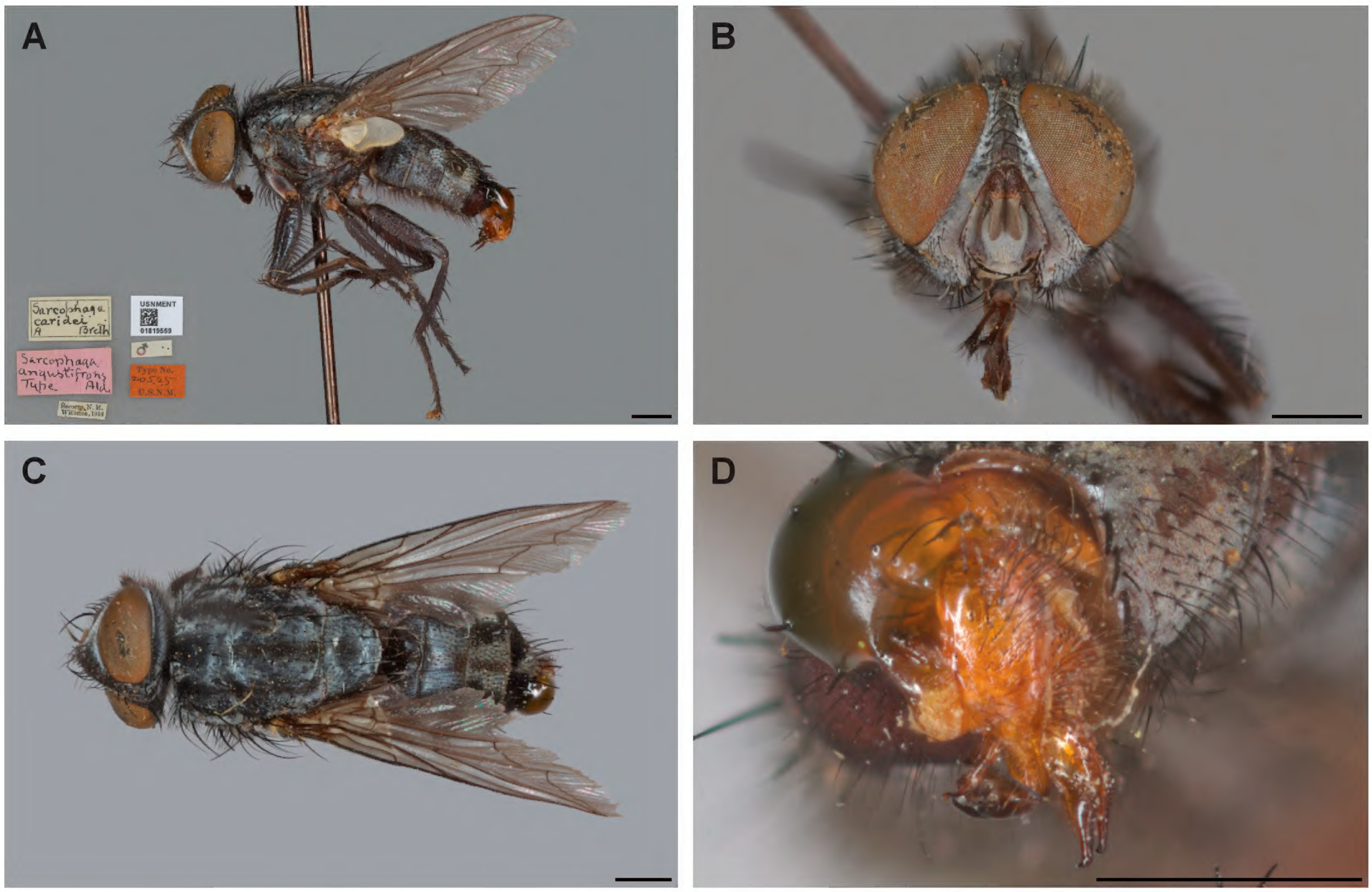

Fig. 3. Holotype male of *Sarcophaga angustifrons* Aldrich, 1916. **A.** Lateral habitus and labels. **B.** Head, frontal view. **C.** Dorsal habitus. **D.** Terminalia, lateral view. Scale bars: 1 mm. Available on http://n2t.net/ark:/65665/30453cedd-1fb5-4129-aa41-ec3963703afe.

species distributed from Canada to Argentina (Pape 1996). Males of both species have narrow frons, about 0.1 times the head width (Fig. 4B), being considered synonymous in previous works (Aldrich 1927, Blanchard 1933, Downes Jr 1965, Rees 1973). In his revision of World *Blaesoxipha*, Pape (1994) differentiated these species by the length of the median stylus in the male terminalia: shorter than the juxtal lobe in dorsal view and, therefore, completely covered by it in lateral view in *B.* (*A.*) *angustifrons* (Fig. 4F, G), and slightly longer than the juxtal lobe, with apex visible in lateral view in *B.* (*A.*) *caridei* (see figs 262, 263 in Pape 1994). According to Pape (1994), the Nearctic species *B.* (*A.*) *aculeata* (Aldrich, 1916) is also similar to *B.* (*A.*) *angustifrons*, differing from it by having the male terminalia exhibiting the cercal apexes divergent in posterior view and less prominently bent in lateral view, and the juxtal lobes diverging from each other with a wider angle (see figs 245–249 in Pape 1994).

Apart from the two hosts recorded above, host records for *B.* (*A.*) *angustifrons* are scarce and, sometimes, not completely clear. As Rees (1973) considered *B.* (*A.*) *angustifrons* and *B.* (*A.*) *caridei* as synonyms, its host list for *B.* (*A.*) *angustifrons* included only the records for *B.* (*A.*) *caridei*. Later, Pape (1994) reported the Nearctic grasshopper *Conozoa carinata* Rehn, 1907 (Acrididae: Oedipodinae) as a host of *B.* (*A.*) *angustifrons*, although the locality was not specified. The remaining published associations are questionable: Mason and Erlandson (1994) listed *B.* (*A.*) *angustifrons* as a probable parasitoid of *Melanoplus bivittatus* (Say, 1825), *M. packardii* Scudder, 1878, and *M. sanguinipes* (Fabricius, 1798) (Acrididae: Melanoplinae), and *Camnula pellucida* (Scudder, 1862) (Acrididae: Oedipodinae) in Canada, based on Rees (1973). However, Rees (1973) did not mention these specific hosts for this fly species. Finally, Danyk et al. (2005) subsequently mentioned *B.* (*A.*) *angustifrons* and other parasitoids reared in Canada from the same four grasshopper species, based on unpublished data. Therefore, aside from the records in *C. carinata*, *T. melanoptera*, and *T. pallidipennis*, the host records found in the literature are pending revision.

Blaesoxipha females rely on visual cues when searching for hosts, often darting at flying or jumping individuals or stalking them on the ground (Blanchard 1933, Lloyd 1951, Rees 1973, Hostetter 2000). They typically deposit a single, well-developed first-instar larva on or in the host, either on the ventral wing surface or injected between the abdominal intersegmental membranes. These flies have been frequently recorded in many grasshopper groups (Pape 1994) and are considered as important agents for biological control (Spencer 1958, Mason and Erlandson 1994, Hostetter 2000, Cingolani et al. 2025). Despite this general importance, successful records of parasitoid flies in *Trimerotropis* species remain considerably scarce. For instance, Rees (1970, 1985) found that tests involving four Palaearctic Sarcophagidae parasitoids on numerous Nearctic grasshopper species, including *Spharagemon campestris* (McNeill, 1901), a species formerly classified as *Trimerotropis*, were unsuccessful. Given that some *Trimerotropis* species, such as *T. pallidipennis*, can significantly impact crops during outbreaks by feeding on a wide variety of plants (Barnes 1960, Otte and Joern 1976), greater knowledge of their natural enemies is essential.

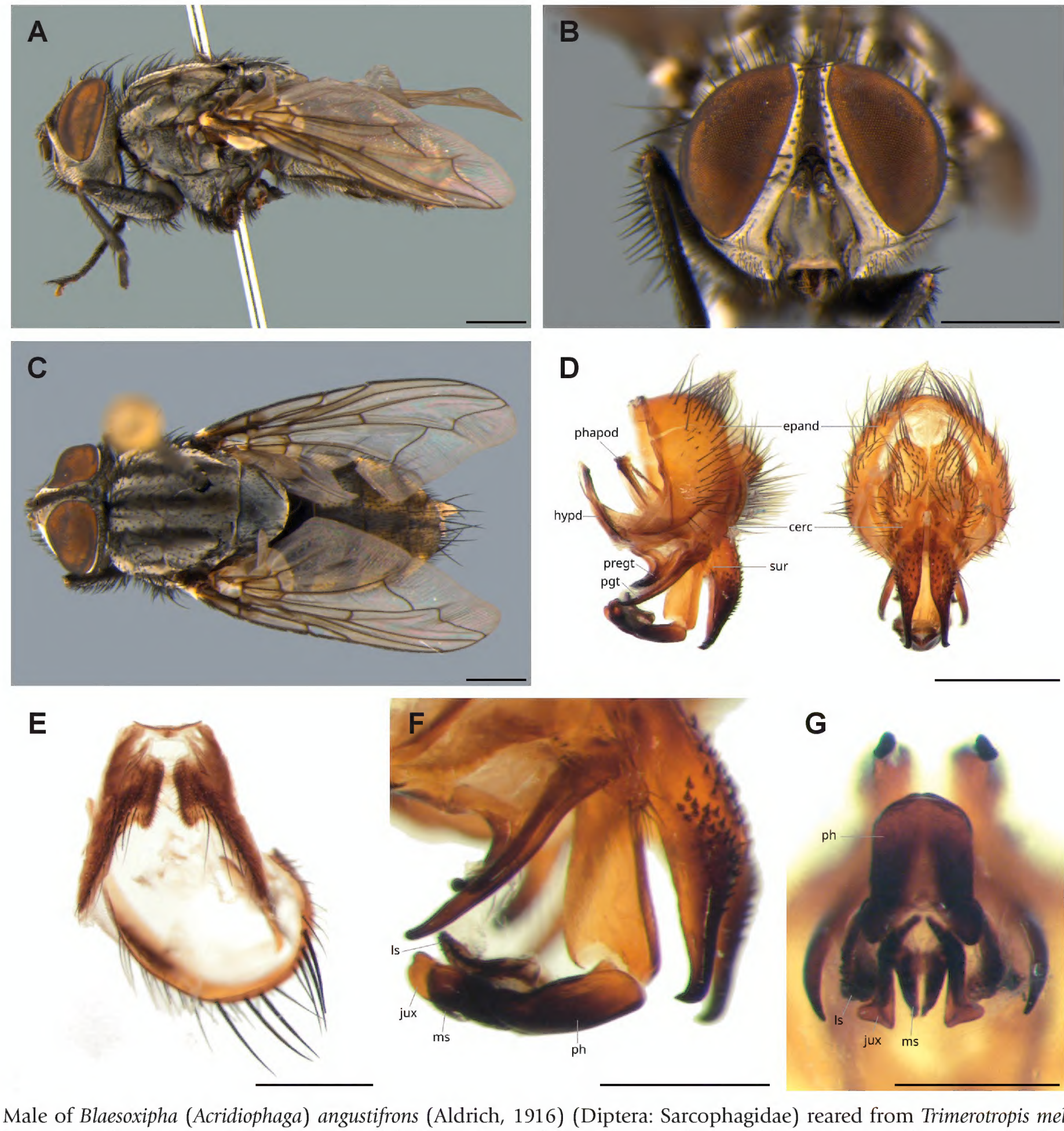

Fig. 4. Male of *Blaesoxipha* (*Acridiophaga*) *angustifrons* (Aldrich, 1916) (Diptera: Sarcophagidae) reared from *Trimerotropis melanoptera* McNeill, 1901 (Orthoptera: Acrididae). **A.** Lateral habitus. **B.** Head, frontal view. **C.** Dorsal habitus. **D.** Male terminalia, lateral and posterior view. **E.** Sternite five, ventral view. **F.** Phallus, lateral view. **G.** Distiphallus, dorsal view. Scale bars: 1 mm (**A–C**); 500 µm (**D, E**); 250 µm (**F, G**). Abbreviations: cerc: cercus; epand: epandrium; hypd: hypandrium; jux: juxta; ls: lateral stylus; ms: medium stylus; pgt: postgonite; ph: phallic tube; phapod: phallapodeme; pregt: pregonite; sur: surstylus.

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